MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

EME4076 – MECHANICAL VIBRATIONS

(ME)

28 OCTOBER 2017
09:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 9 pages including cover page with 5 Questions and 3 appendices.

2. Attempt **FOUR** out of **FIVE** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

Figure Q1(i) shows a 60-g bullet is fired with a velocity of 300 m/s at the 5-kg block mounted on a damped flexible light cantilever beam. The bullet is embedded in the block which is vibrated with a displacement-time curve as shown in Figure Q1(ii). Determine

(a) the damping constant, c, and the spring constant, k, of the system,

[12 marks]

(b) how many cycles it is going to take to reduce the amplitude of vibration to at least 0.1 mm and the time for this to occur, and

[4 marks]

(c) the maximum deceleration of the system.

[9 marks]

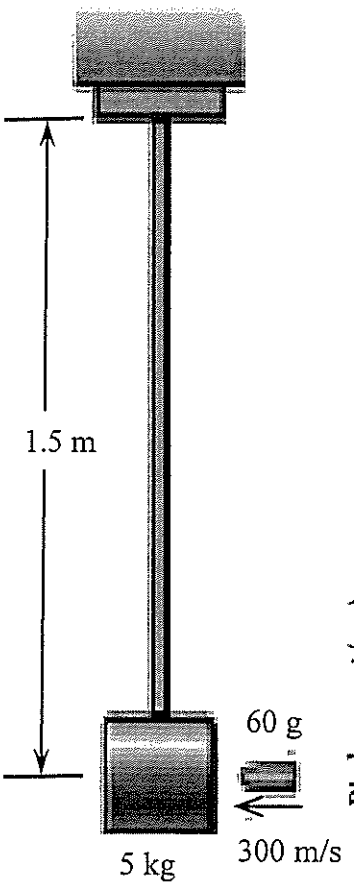


Figure Q1(i)

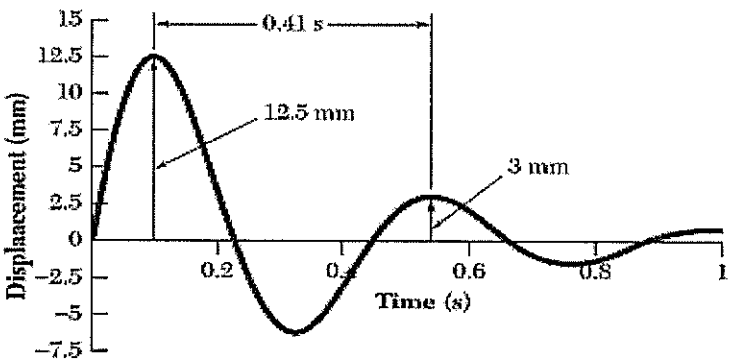


Figure Q1(ii)

Continued .....

Question 2

A milling machine of mass 450 kg operates at 1800 rpm and has an unbalance which causes a harmonic repeated force of magnitude 20 kN. An isolation system for the machine consists of a damped isolator with damping ratio of 0.05 and a steel plate to add mass to the machine. Design the isolation system such that all of the following conditions are met:

(i) The transmitted force during operation is limited to 4000 N.

(ii) The maximum allowable amplitude of vibration during start up is limited to 10 mm.

(iii) The amplitude of vibration during operation is limited to 1 mm.

To design the isolation system to meet the three conditions specified, the following steps are suggested:

(a) Select the isolator damper that will meet the condition (i).

[8 marks]

(b) Using the isolator of part (a), check whether it can meet the condition (ii). If not, add the weight to the system. Notice that during starting up of the machine, the rotation speed of the machine will pass through the natural frequency of the system.

[9 marks]

(c) Do the final checking for condition (iii).

[8 marks]

Continued .....

Question 3

Figure Q3(i) shows a soil compaction machine which can be modeled as shown in Figure Q3(ii). The tractor of the machine has mass of m_1 which is connected to the roller by a flexible hitch. The hitch can be modeled as a spring with stiffness of k. The roller has mass of m_2 and radius of r can roll without slipping on a horizontal plane as shown in the figure.

(a) Derive the equation of motion of the system in terms of x_1, the displacement of the tractor, and x_2, the displacement of the roller center.

[12 marks]

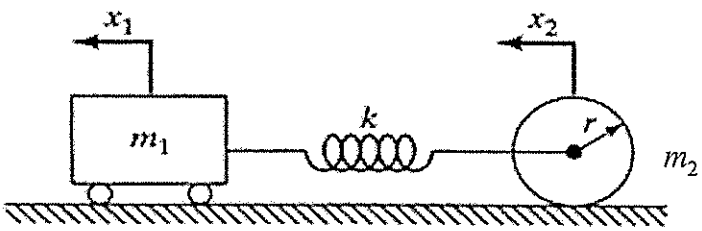
(b) In such a system $m_1 = 2\,\text{t}$, $m_2 = 1\,\text{t}$ and $r = 1\,\text{m}$. The spring consists of two sections in series; one having a stiffness of 360 kN/m and the other 90 kN/m. Notice that $1\,\text{t} = 1000\,\text{kg}$.

(i) Find the natural frequencies of the system.

(ii) The node of the vibration is in the weaker spring, which is 250 mm long is adjacent to the 1 t mass. Find the distance of the node from this mass.

[7+6 marks]

(i)



(ii)

Figure Q3

Continued .....

Question 4

Figure Q4 shows a block of mass m is suspended from a rigid frame which is undergone vertical displacement $y(t) = Y \sin \omega t$ by a shaker. When the system is at equilibrium, knowing that the distance between the block and the bottom of the frame is b.

(a) Derive the equation of motion of the system in terms of x.

[7 marks]

(b) Determine the range of ω for which the block will not hit the bottom of the frame.

[13 marks]

(c) If the shaker is operated at a speed of 90 percent of the speed at resonance, determine amplitude Y of displacement provided by the shaker such that the block will just hit the bottom of the frame.

[5 marks]

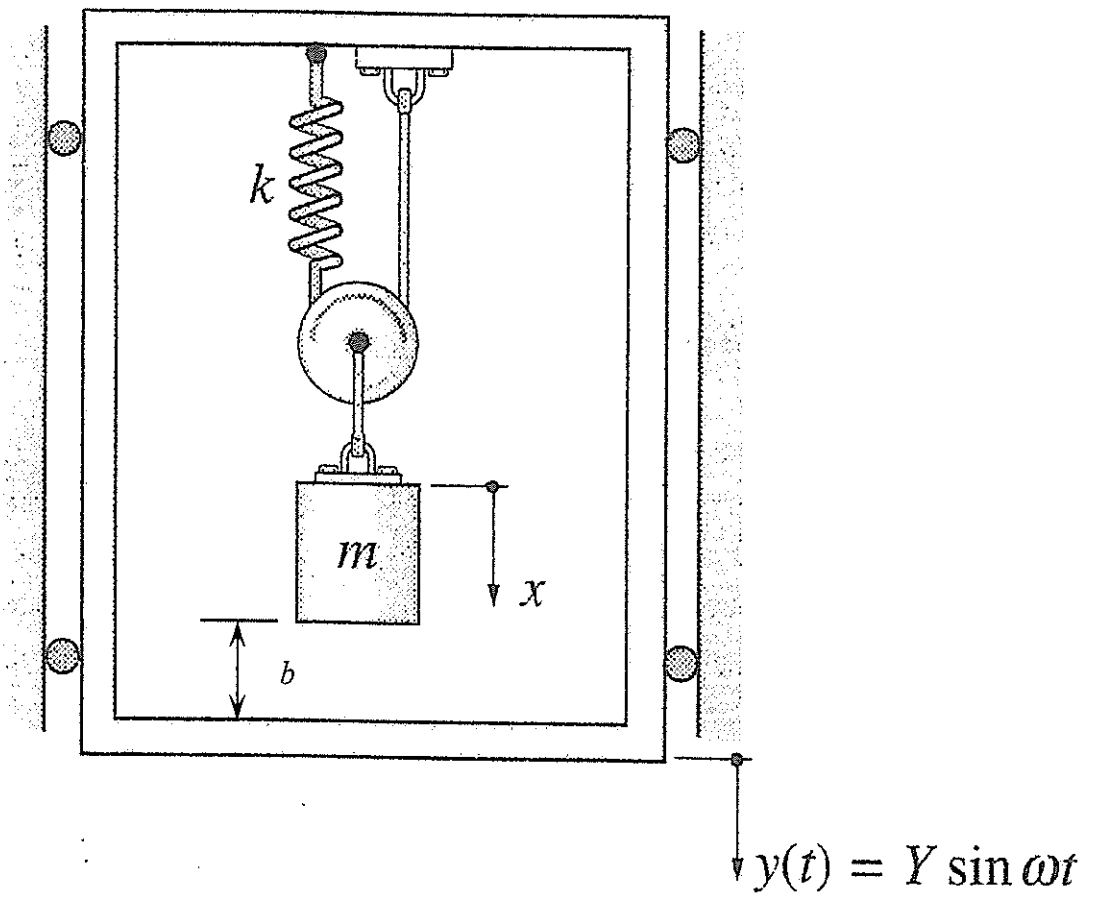


Figure Q4

Continued .....

Question 5

Figure Q5(i) shows a parent pushes a child on a swing whose chains have a length of l m . The mass of the child is m kg. The force exerted by the parent is approximated by a rectangular pulse with magnitude F_0 and duration t^* as shown in the Figure Q5(ii). Assume that the system is free from damping, the pushing force is applied tangent to the path, and the mass of the chain is negligible.

(a) Determine the response of the system for the time $t \geq t^*$.

[10 marks]

(b) Show that the maximum displacement θ_{max} of the system for the time $t \geq t^*$ is

$$\theta_{max} = \frac{F_0}{mg}\left(2\sin\left(\frac{\omega_n t^*}{2}\right)\right)$$

Hint: use identity $\sin(a)-\sin(b) = 2\cos\big((a+b)/2\big)\sin\big((a-b)/2\big)$

[10 marks]

(c) Show that θ_{max} is maximum, that is $\theta_{max} = (2F_0)/(mg)$, when the length of the chain is $l = \left(t^*/\pi\right)^2 g$

[5 marks]

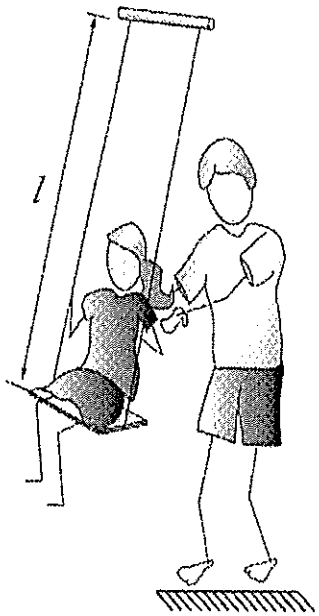


Figure Q5(i)

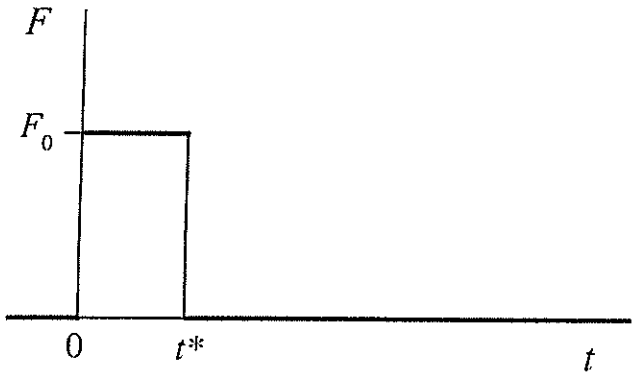


Figure Q5(ii)

Continued .....

Appendix 1

Vibrations

Equations of Motion

$$m\ddot{x} + c\dot{x} + kx = F_0 \sin \omega t$$

General Solution

$$x(t) = x_c(t) + x_p(t)$$

$$x_p(t) = D \sin(\omega t - \varphi)$$

$$D = \frac{F_0 / k}{\sqrt{[1 - r^2]^2 + (2\zeta r)^2}} \qquad where \quad r = \frac{\omega}{\omega_n}$$

$$\varphi = \tan^{-1} \frac{2\zeta r}{1 - r^2}$$

$$x_c(t) = D_1 e^{\lambda_1 t} + D_2 e^{\lambda_2 t} \qquad \zeta > 1$$

$$x_c(t) = (B + Ct) e^{-\omega_n t} \qquad \zeta = 1$$

$$x_c(t) = e^{-\zeta \omega_n t} (B \cos \omega_d t + C \sin \omega_d t) \qquad \zeta < 1$$

$$\omega_n = \sqrt{k/m} = 2\pi f_n, \qquad f_n = \frac{1}{\tau_n} = \frac{\omega_n}{2\pi}$$

$$\zeta = \frac{c}{2m\omega_n}$$

$$\lambda_{1,2} = -\zeta \omega_n \pm \omega_n \sqrt{\zeta^2 - 1} \qquad \zeta \geq 1$$

$$\omega_d = \omega_n \sqrt{1 - \zeta^2} \qquad \zeta < 1$$

Force and Displacement Transmissibility

$$\frac{F_T}{F_0} = \frac{X}{Y} = \left[\frac{1 + (2\zeta r)^2}{(1 - r^2)^2 + (2\zeta r)^2} \right]^{\frac{1}{2}}$$

Rotating Unbalance: Amplitude of Response

$$X = \frac{m_0 e}{m + m_0} \frac{r^2}{\sqrt{(1 - r^2)^2 + (2\zeta r)^2}}$$

Fourier's series

$$x(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} [a_n \cos n\omega t + b_n \sin n\omega t]$$

$$a_n = \frac{2}{\tau} \int_0^{\tau} x(t) \cos n\omega t \, dt \qquad b_n = \frac{2}{\tau} \int_0^{\tau} x(t) \sin n\omega t \, dt$$

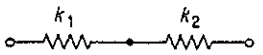
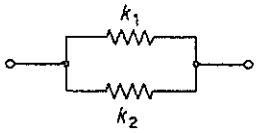
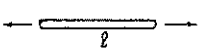
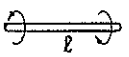
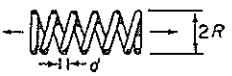
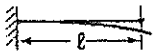
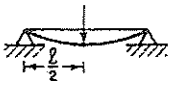
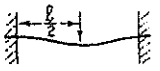
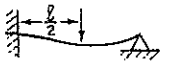
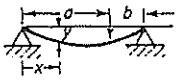
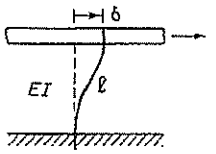
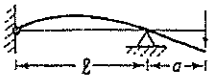
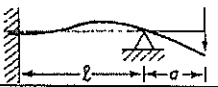
Unit response function (underdamped)

$$h(t - \tau) = \frac{e^{-\xi \omega_n (t - \tau)}}{m\omega_d} \sin \omega_d (t - \tau)$$

Continued .....

Appendix 2

Table of Spring Stiffness

	$k = \dfrac{1}{1/k_1 + 1/k_2}$	
	$k = k_1 + k_2$	
	$k = \dfrac{EI}{l}$	I = moment of inertia of cross-sectional area l = total length
	$k = \dfrac{EA}{l}$	A = cross-sectional area
	$k = \dfrac{GJ}{l}$	J = torsion constant of cross section
	$k = \dfrac{Gd^4}{64nR^3}$	n = number of turns
	$k = \dfrac{3EI}{l^3}$	k at position of load
	$k = \dfrac{48EI}{l^3}$	
	$k = \dfrac{192EI}{l^3}$	
	$k = \dfrac{768EI}{7l^3}$	
	$k = \dfrac{3EIl}{a^2b^2}$	$y_x = \dfrac{Pbx}{6EIl}(l^2 - x^2 - b^2)$
	$k = \dfrac{12EI}{l^3}$	
	$k = \dfrac{3EI}{(l + a)a^2}$	
	$k = \dfrac{24EI}{a^2(3l + 8a)}$	

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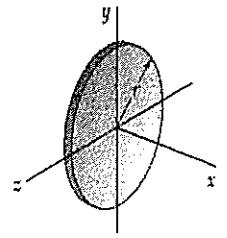
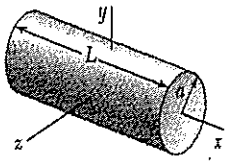
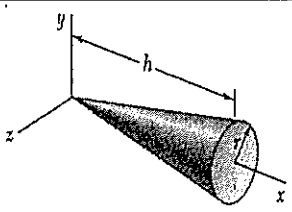
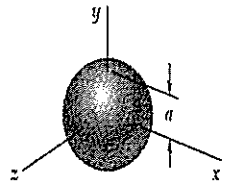
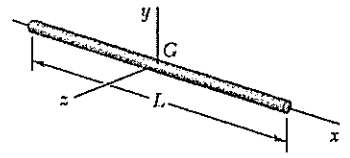
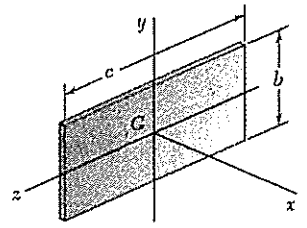
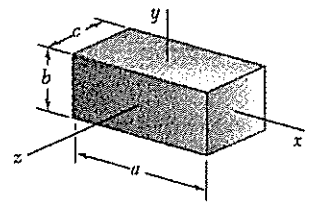
Appendix 3: Mass Moment of Inertia of Homogenous Solids

	$I_x = \frac{1}{2}mr^2$ $I_y = I_z = \frac{1}{4}mr^2$
	$I_x = \frac{1}{2}ma^2$ $I_y = I_z = \frac{1}{12}m(3a^2 + L^2)$
	$I_x = \frac{3}{10}ma^2$ $I_y = I_z = \frac{3}{5}m(\frac{1}{4}a^2 + h^2)$
	$I_x = I_y = I_z = \frac{2}{5}ma^2$
	$I_y = I_z = \frac{1}{12}mL^2$
	$I_x = \frac{1}{12}m(b^2 + c^2)$ $I_y = \frac{1}{12}mc^2$ $I_z = \frac{1}{12}mb^2$
	$I_x = \frac{1}{12}m(b^2 + c^2)$ $I_y = \frac{1}{12}m(c^2 + a^2)$ $I_z = \frac{1}{12}m(a^2 + b^2)$

End of Paper